Cloud-Radiation and SST Feedbacks in the Tropical Western Pacific

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OVERVIEW

This proposal addresses aspects of cloud-radiative feedback mechanisms in the tropical warm pool region. Specifically we focus on the following issues:

- Impact of three-dimensional cloud structure on the radiation field
- Interactions of convection with large-scale atmospheric dynamics and thermodynamics, including the impact of cloud organization and vertical structure on atmospheric latent heating and the precipitation processes
- Interactions of clouds with the sea surface temperature.

This project uses the ARM datasets in the Tropical Western Pacific (TWP) including those obtained in the tropical oceans from research ship platforms. To date, these include the Combined Sensor Program and Nauru99, as well as the JASMINE datasets. The first IOP for the Joint Air-Sea Monsoon Interaction Experiment (JASMINE) was conducted from April to June 1999 in the eastern Indian Ocean and the equatorial portion of the Bay of Bengal, aboard the NOAA R/V Ronald H. Brown. Data has been collected during JASMINE that is almost identical to that being collected on the Ronald H. Brown for Nauru99, including archival of ECMWF column data for five points in the Bay of Bengal. The advantage of analyzing the cloud, radiation, and ocean surface data in the Indian Ocean along with that in the tropical western Pacific Ocean is that the two regions have very different dynamical-convective regimes; hence, this comparison will help us understand the representativeness of the TWP convective dynamics, cloud-radiative characteristics, and their feedbacks with the sea surface temperature. An interesting corollary analysis will be comparison of the ECMWF Single-Column Model (SCM) output with the JASMINE and Nauru99 cloud and radiation data, to assess the relative performance of the ECMWF parameterizations in these two different convective-dynamic regimes.

We plan to continue the collaboration with ECMWF initiated under our previous support, where we have included our parameterization of the diurnal variation of SST into an experimental version of the ECMWF model. Simulations showed that SST diurnal variability was found to alter the tropical base state and also the midlatitude climatology of the model. Comparison of simulations with 5-day specified SST versus those that include the diurnal variability will allow us to investigate the aspect of the cloud-SST feedback associated with diurnal variations in SST, the large-scale cloud fields and the large-scale atmospheric dynamical fields in both the TWP and the Indian Ocean regions.

(1) WARM POOL SURFACE ENERGY BALANCE

We have completed a comparison of the warm pool energy balances of the Indian and Pacific Oceans (Fasullo and Webster 1999). It is found that in both warm pools that shortwave and evaporative surface

flux variability play an important role though the relative importance depends on the tendency of the SST and the geographic location under consideration. Differences exist in the relative heating roles of the flux anomalies among episodes within a fixed location. Differences also exist between the Indian and the Pacific oceans. A more pronounced annual cycle exists in the eastern Indian Ocean than elsewhere and the SST seems less effected by thermal forcing. Finally, the analysis in the paper suggests that the SST is not regulated by a simple thermodynamical response. SST is regulated by a sequence of events that include the large scale dynamic response of the tropical atmosphere in addition to (and responding to) the local thermodynamical responses. There are also suggestions that in both of the basins that intraseasonal variability is a critical component of the annual heat balance and the regulation of SST. Finally, the signatures of the intraseasonal and interannual variability in the tropical warm pools are shown to be of a very large scale.

Finally, the study on westerly wind bursts in the TWP region undertaken during earlier ARM funding has finally been published (Fasullo and Webster 2000).

(2) COMPARISON OF FLUXES OBTAINED IN JASMINE AND NAURU99

The Joint Air-Sea Monsoon Interaction Experiment (JASMINE) was conducted in the eastern Indian Ocean-southern Bay of Bengal immediately prior to Nauru99. During the months of April-May extensive observations were made in the eastern Indian Ocean. These are documented in Webster et al. (2000) which is in the final stage of preparation for submission. Rather than providing details of the overall observations made during JASMINE, we present a summary of the surface fluxes during different parts of the experiment and compare these with both TOGA COARE surface fluxes and those observed during Nauru99.

Table: Comparison of Warm Pool Surface Fluxes of the Indian Ocean Obtained During Jasmine with Those Obtained in the Pacific Ocean During TOGA COARE and Nauru-99. In addition, satellite determined fluxes for the TOGA COARE period are also listed (W m-2).

	S	**LW**	**S**	**LH**	**Rain**	**Net**
PACIFIC						
TC Pilot	197	-43	-12	-116	-3	+22
TIWE	219	-51	-4	-101	-0	+61
TC-Period 1	222	-58	-7	-89	-1	+65
TC-Period 2	166	-46	-11	-117	-4	-12
TC-Period 3	190	-51	-10	-112	-3	+13
CSP	225	-48	-6	-109	-2	+59
Nauru99	216	-54	-5	-123	-1	+33
Average Pac	205	-50	-8	-110	-2	+34
Average TC	176	-52	-9	-106	-2	+22
INDIAN OCEAN						
JASMINE Phase II	205	-43	-9	-125	-2	+27
Phase II: Undist	260	-49	-5	-115	-0	+92
Phase II: Dist	162	-31	-17	-162	-7	-89
JASMINE Phase III	229	-38	-3	-92	-1	+96
Average JASMINE	214	-40	-9	-125	-2	+31
TOGA COARE SATELLITE						
TC-Period 1	252	-63	-3	-87	-1	+98
TC-Period 2	211	-71	-8	-133	-3	-4
TC-Period 3	214	-64	-7	-109	-3	+29
Average TC	226	-66	-6	-110	-2	+41

The flux data collected during JASMINE allows an initial comparison of net flux and variability between the Indian and Pacific oceans. The table lists data from a number of western Pacific Ocean experiments and from JASMINE. The average fluxes for JASMINE Phase II are very similar to the average fluxes for the TOGA COARE period and the recent Nauru99 experiment. However, this similarity may be deceptive and covers up the large intraseasonal variability in the Indian Ocean. The extent of the intraseasonal variability during TOGA COARE can be seen by comparing the three periods of the experiment. The first period (TC-period 1) was a relative quiescent period with a net flux of +65 W m-2. The second period (TC-period 2) contained one of the largest westerly wind bursts recorded in the western Pacific Ocean. The net flux for the period was -12 W m-2. The next period possessed above average winds and showed a net flux of +13 W m-2. While the Pacific Ocean fluxes vary between +65 and -12 W m-2, the Indian Ocean fluxes oscillated between +/-90 W m-2 throughout the lifetime of a monsoon intraseasonal oscillation. The major differences between the disturbed periods of the Pacific Ocean and the Indian Ocean appears to be strength of the winds and reduced insolation during disturbed periods of the monsoon. From this comparison, it is clear that the results of western Pacific warm pool experiments cannot be simply transferred to the Indian Ocean, and vice versa.

(3) SATELLITE REMOTE SENSING OF CLOUDS AND SURFACE FLUXES

We have completed a study that was initiated during TOGA COARE of derivation of the complete surface energy balance in the tropical western Pacific Ocean at high resolution (50 km, 3 hr). The satellite derived fluxes have been evaluated extensively using ship and aircraft measurements and also atmospheric and ocean mixed layer energy budgets. We are now assembling all in situ ship-based data in the tropical oceans to validate and improve the algorithms. An international workshop was convened in Boulder (Aug 1999; Curry and Webster were on organizing committee) to address strategies for determination of surface fluxes from satellite. Note that in the table that the fluxes derived from satellite during TOGA COARE are also listed. The algorithms used in the derivations are discussed in Curry et al. 1999. Except for a bias in the derived surface radiation, the fluxes are fluxes are encouragingly very similar to the in situ measurements.

(4) AEROSONDE INSTRUMENTATION

We have been conducting research into identifying suitable instruments for the Aerosonde to be used in conducting future IOPs at the TWP sites. The instruments identified thus far (that extend beyond basic meteorological measurements) include:

- Heimann KT11.85 pyrometer (surface temperature)
- GPS reflectance (surface wind speed)
- Pyranometer (LICOR, Kipp and Zonen)
- SW radiation fluxes GPS (3D water vapor profiles).

We are working to identify suitable IR flux measurements and some lightweight cloud and aerosol instrumentation.

(5) PUBLICATIONS

Curry, J. A. et al., 1999: High-resolution satellite-derived dataset of the ocean surface fluxes of heat, freshwater and momentum for the TOGA COARE IOP. *Bull. Amer. Meteorol. Soc*., 80, 2059-2080.

Fasullo, J. T. and P. J. Webster, 2000: Structure of the ocean-atmosphere system in the tropical western Pacific during strong westerly wind bursts. *Q. J. Roy. Met. Soc*., 126, 899-924.

Fasullo, J. T. and P. J. Webster, 1999: Warm pool sea surface temperature variability in relation to the surface energy balance. *J. Clim*., 12, 1292-1305.

Webster, P. J., et al. 2000: The Joint Air-Sea Monsoon Interaction Experiment (JASMINE): Exploring the Intraseasonal Variability in the South Asian Monsoon. In preparation. To be submitted to the *Bull. Amer. Meteor. Soc*.